XMM-Newton EPIC PN Calibration Overview

U Briel
MPE Garching

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STATUS OF THE EPIC/PN CALIBRATION

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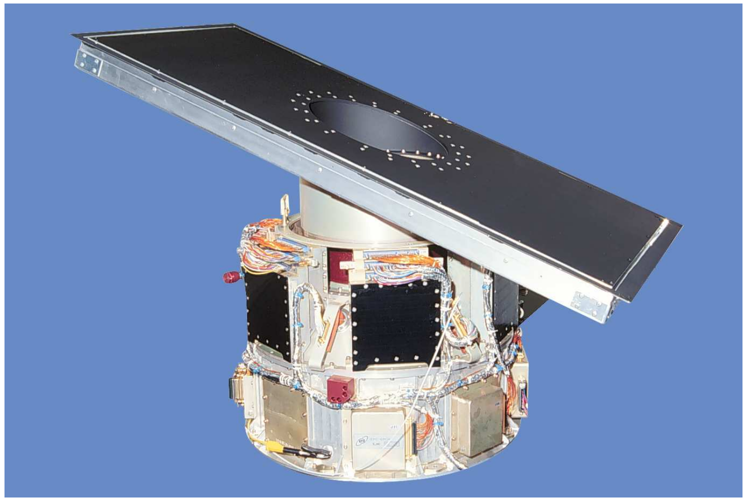
OVERVIEW

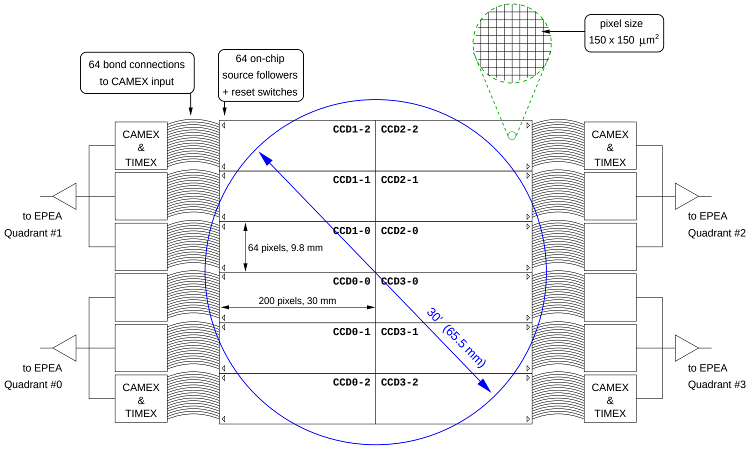
- short description of the pn-camera including the different modes
- in-orbit calibration philosophy
- calibration status/results
  - imaging capabilities
  - effective area
  - charge transfer inefficiency
  - detector response matrix
  - background
- summary

DESCRIPTION OF THE PN-CAMERA



Photograph of the pn camera

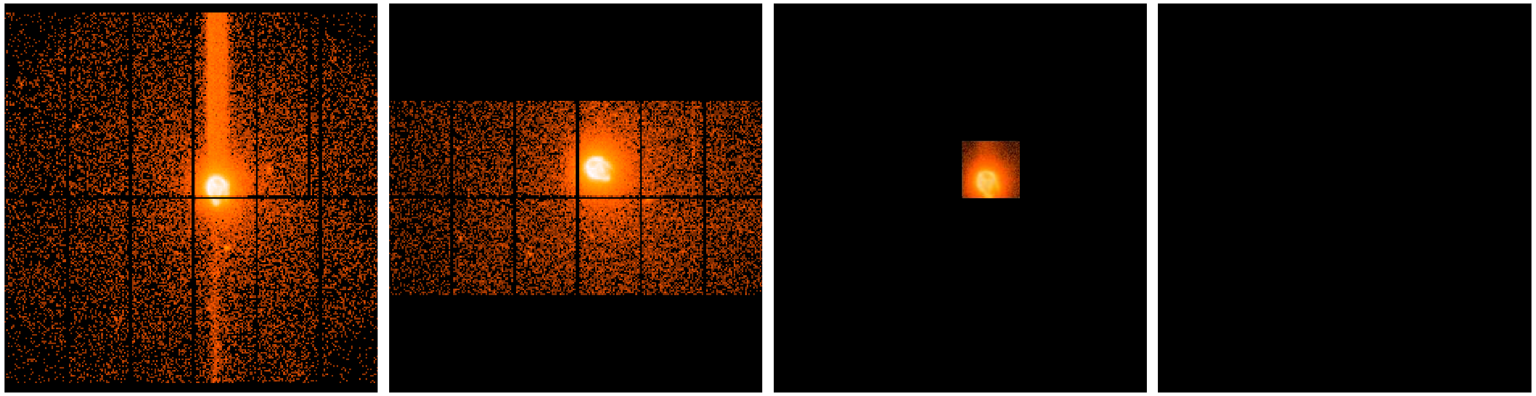
- Detector housing
- Electronic boxes
- Radiator to keep CCDs at a temperature of -90 DegC



Layout of the CCD focal plane

- 4 redundant quadrants
- each with 3 CCDs of 1×3 cm^2
- each with 64×200 pixels
- all CCDs on **one** Silicon wafer

READ-OUT MODES OF THE PN-CAMERA



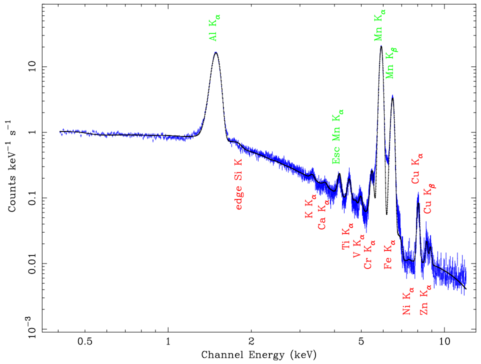
IN-ORBIT CALIBRATION PHILOSOPHY

CAL/PV Phase

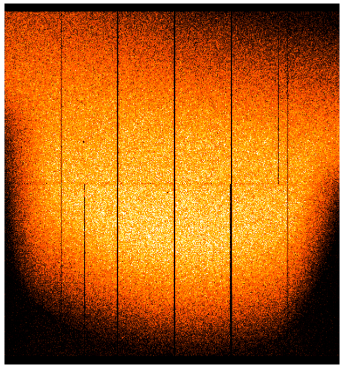
- 2dn Feb. to 24th June of 2000
  22 CAL and 29 PV targets

Internal CAL Source

- Fe^{55} radioactive source with Al-target
- 1 h observations in almost each orbit for monitoring

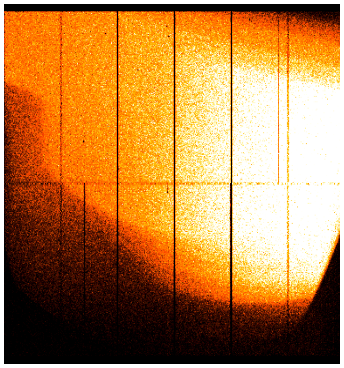


spectrum of internal CAL source



internal CAL source: Al-K

- so far 6 long (>10 h) observations for CTI detemination



internal CAL source: Mn-K

Regular CAL observations of targets

- N132D or 1E0102-72 every two month for eff area, gain, offset
- NGC2516 once after eclipse season for platescale & boresight
- MS1229.2-6430 appr. twice per year for contamination

Extra CAL observations

- Cas-A, Vela, Coma, ... for fine-tuning of CTI

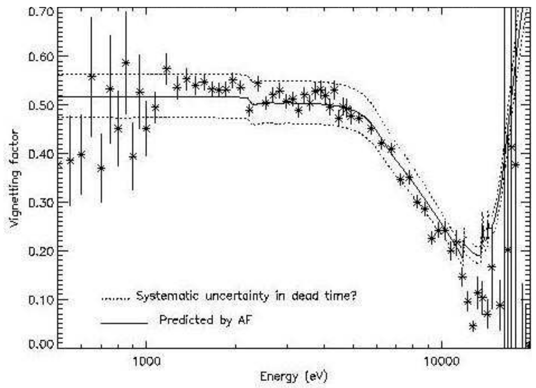
CAL STATUS/RESULTS: IMAGING CAPABILITIES

FM3 Point Spread Function

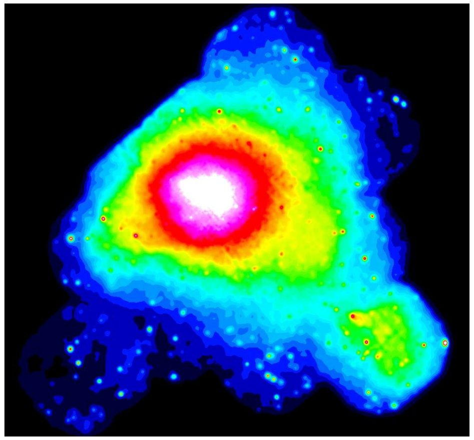
- point spread function (left) and encircled energy (right) of mirror module FM3, measured at Panter; solid line: 1.5 keV, dotted line: 8 keV
- fairly weak dependence of the psf and eef on energy
- pn-camera with 4 arcsec pixels is slightly under-sampling the psf
- in-orbit performance investigation is under way
- see also Poster by Simona Ghizzardi and Silvano Molendi (WA2-4)

CAL STATUS/RESULTS: IMAGING CAPABILITIES

FM3 Vignetting



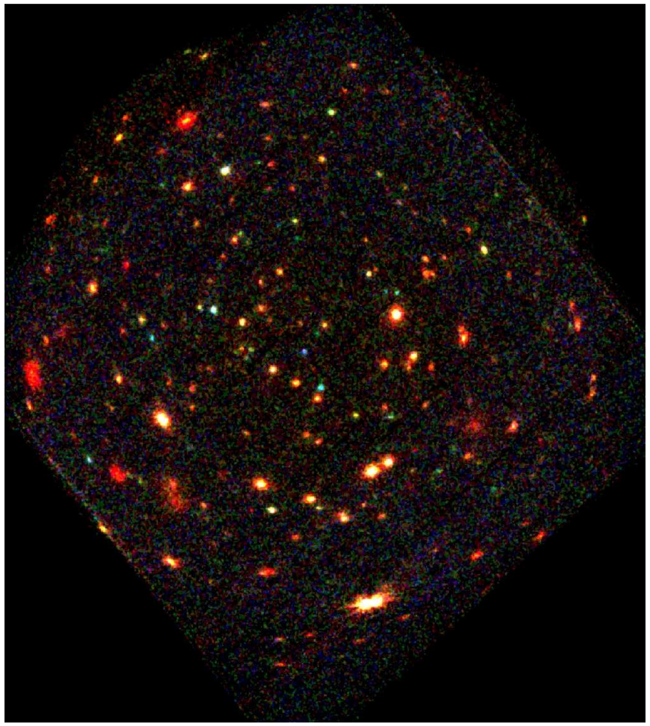
- measurement (data points) and prediction (solid line) of the vignetting at 10 arcmin off-axis
- measurement done in orbit on Abell496 (courtesy J. Bleeker)
- consistent with result from Coma measurements



- Coma mosaic of 14 observations
- vignetting and exposure corrected
- smooth surface brightness across neighbouring fields

CAL STATUS/RESULTS: IMAGING CAPABILITIES

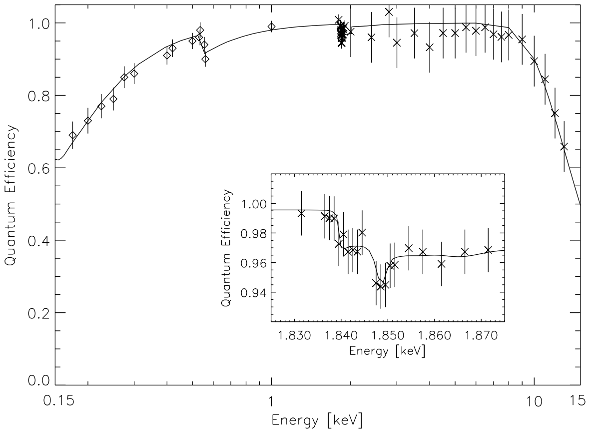
Relative/Absolute Astrometry



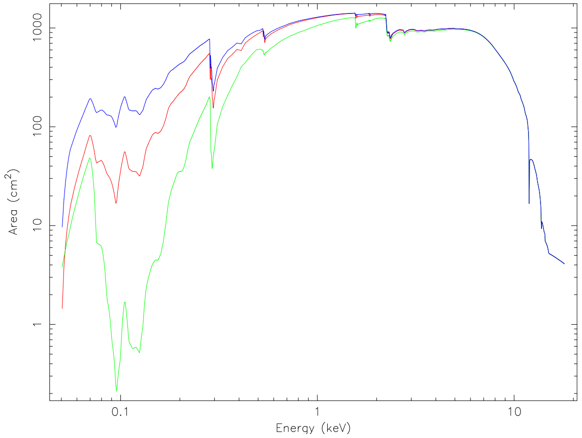
XMM-Newton observation of the Lockman Hole
(courtesy G. Hasinger)

- offset between actual and required pointing direction (when the guide stars are correctly found): $<$ **10 arcsec**
- drift of the spacecraft, which is measurable and correctabl: $<$ **2 arcsec per hour**
- absolute astrometry (done on fields like the Lockman Hole or NGC 2516): $<$ **5 arcsec**
- relative astrometry within the FOV of the focal plane: $<$ **1 arcsec**

CAL STATUS/RESULTS: EFFECTIVE AREA

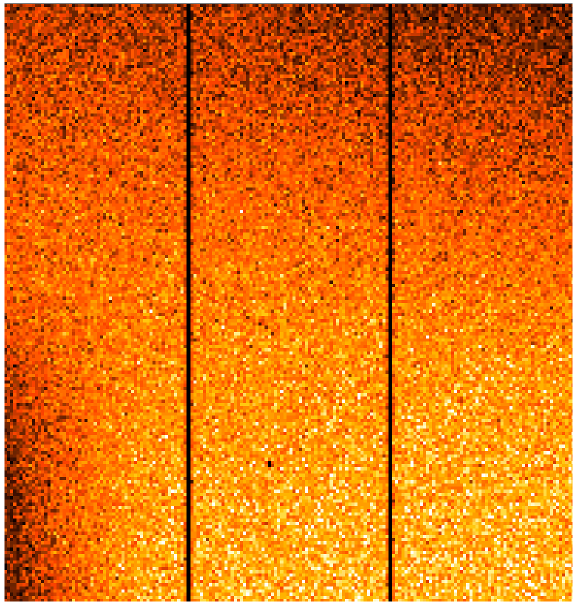


- quantum efficiency of the pn-CCDs
- very high QE at high energies: 300μmm Si fully depleted
- very high QE at low energies: back-illuminated CCDs, thin entrance window
- below 1 keV the detector threshold (80 eV) has to be taken into account



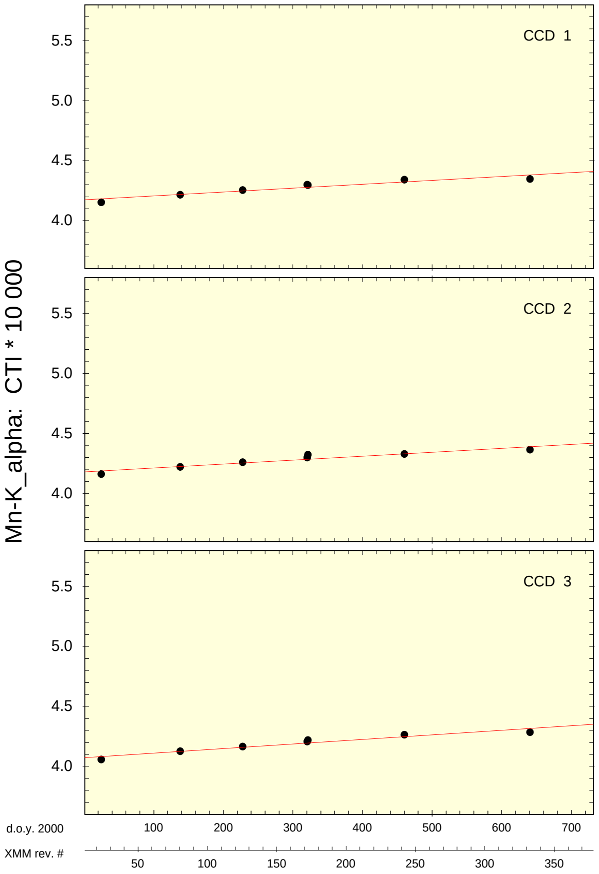
- effective area of FM3 – pn-Detector combination including the filters
- filter absorptions measured on ground (Bessy, Orsay, Moxtec)
- mirror reflect. measured in Panter and CSL and modeled by ray-tracing, using opt. constants
- in-orbit measurements of continuum sources used to improve effective area around edges

CAL STATUS/RESULTS: CHARGE TRANSFER EFFICIENCY



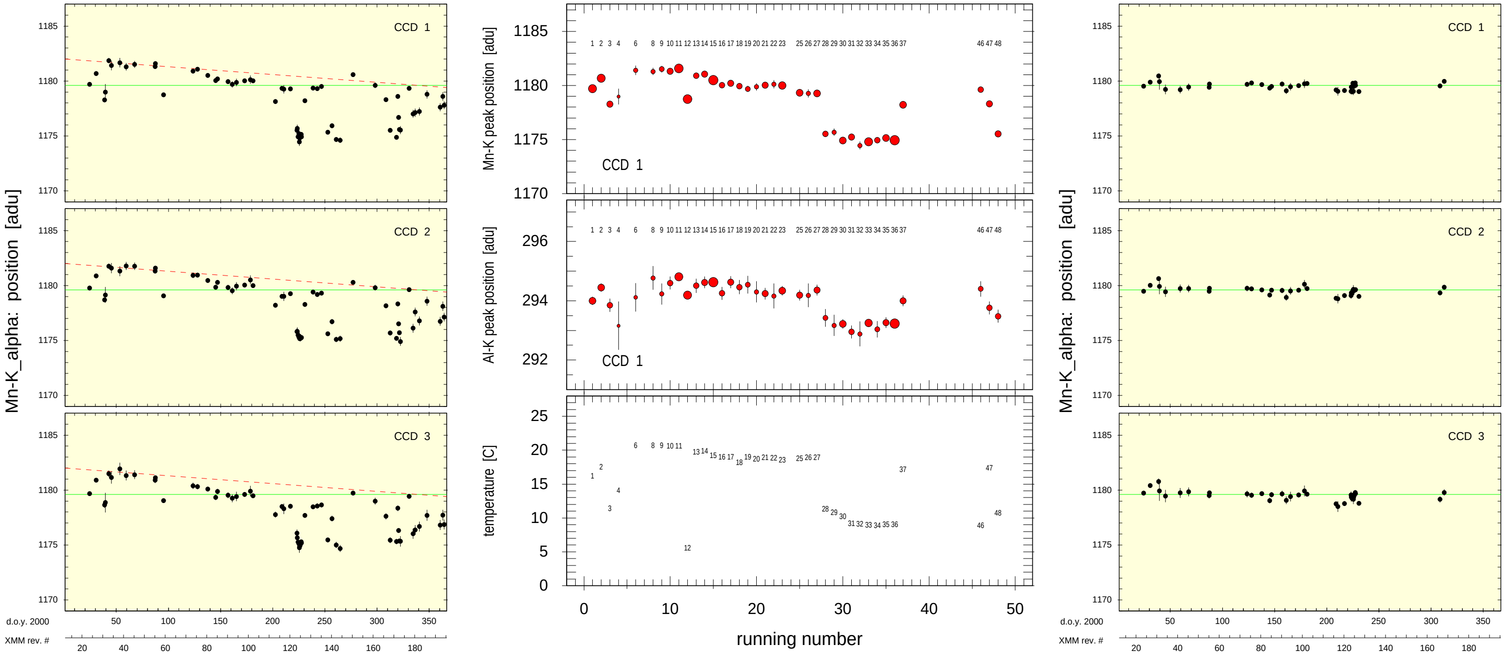
- CTE calibrated on ground for different energies, monitored in orbit using the internal calibration source
- CTE is energy dependent: .9990/shift and .9996/shift for Fe-L (0.68 keV) and Ge-K(9.89 keV) resp.
- model has been developed which is used in the SAS to correct for the CTE
- see also Poster by K. Dennerl et al. (WA2-8)

CAL STATUS/RESULTS: LONG–TERM CTE DEGRADATION



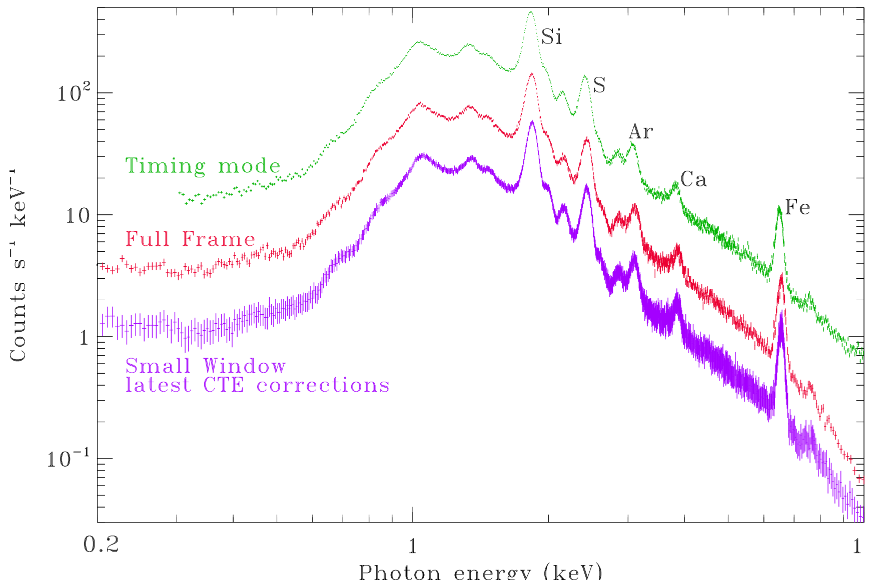
- so far 6 very long (>10 hours) internal calibration source observations performed
- statistics is sufficient to determine the CTE for those observations
- a clear long–term degradation of CTE is found, consistent with expectations
- the degration (for the Mn-K line) is $\sim 2 \times 10^{-5}$/yr
- no clear jumps are seen at times with extremely high solar activity
- CCF exists and correction can be applied in the SAS
- see also Poster by K. Dennerl et al. (WA2-8)

CAL STATUS/RESULTS: GAIN/CTI AS FUNCT. OF TEMP.



- Temperature of electronic boxes is not regulated and is sensitive to on/off status of the other detectors
- clean correlation of quadrant electronic box temp. and peak positions of cal source
- CCF exists and correction can be applied in the SAS
- see also Poster by K. Dennerl et al. (WA2-8)

CAL STATUS/RESULTS: CTI CORRECTION IN DIFF. MODES

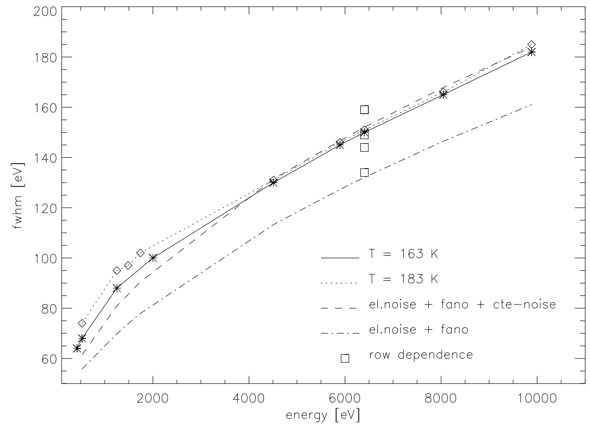


- several targets with prominent lines have been observed to refine and check the CTI correction in the different read-out modes
- see also Posters by
  M. Kirsch et al. (WA2-6)
  V. Zavlin et al. (WA2-15)

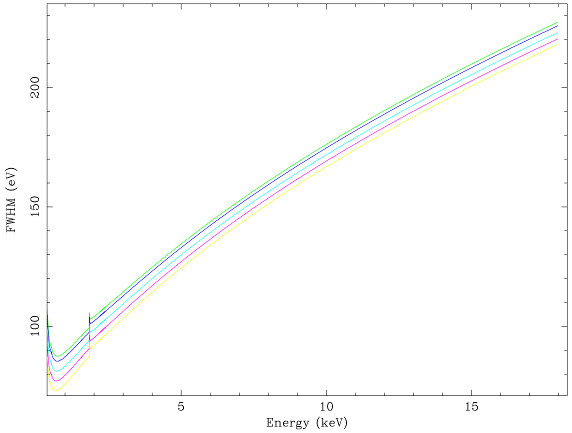
- the example shown is the SNR Cas-A in FF, SW and TI mode
- the line positions agree within 5 eV for the different modes
- the latest CTI correction for the SW mode is not beeing released yet
- for the LW mode, work is in progress

CAL STATUS/RESULTS: DETECTOR RESPONSE MATRIX

Spectral Resolution



- ground measurements at different temperaturs:
  rhombs at - 90 DegC; asterisk at - 110 DegC
  integrated over 1 CCD
- theoretical curves overlayed
- also indicated is the row–dependence of the resolution



- spectral resolution, deduced from the detector response matrixes
- colors denote different distances from the read-out nodes
- see also Poster by F. Haberl et al. (WA2-14)

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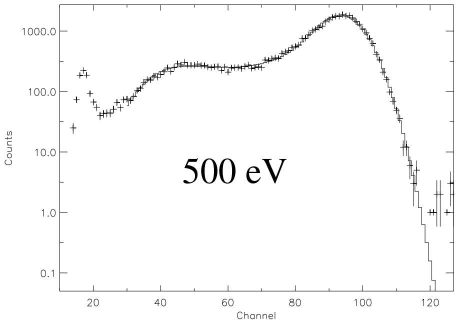
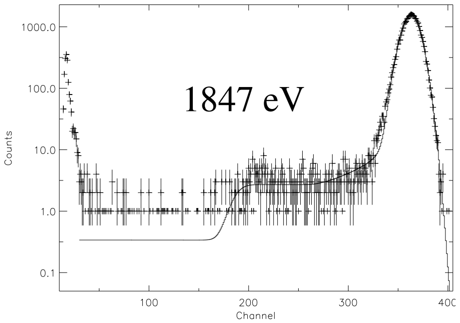
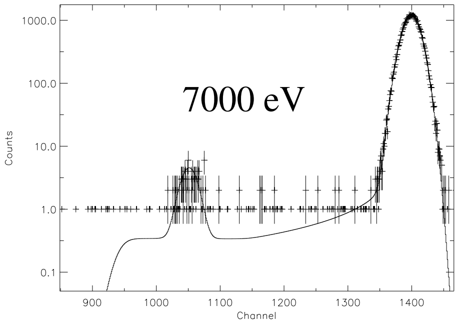
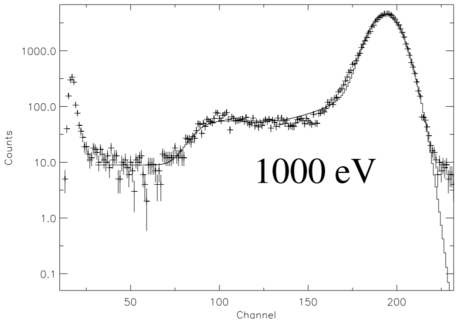
CAL STATUS/RESULTS: DETECTOR RESPONSE MATRIX

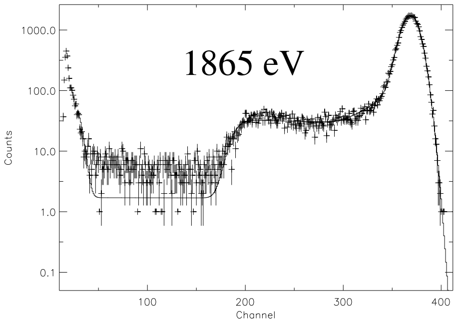
Spectral response to monochromatic X-rays (Synchrotron – Orsay)









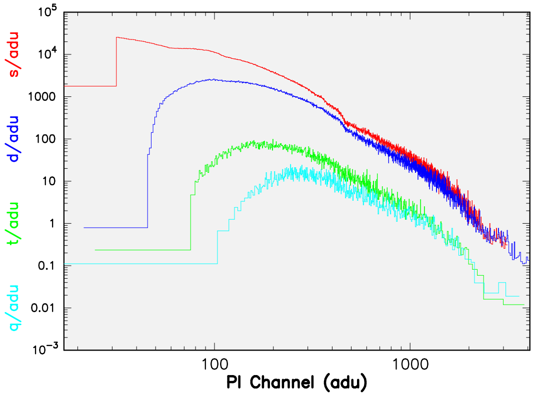


- data averaged over 1 CCD
- solid line: partial event model
- ”shoulder” and ”flat shelf” visible

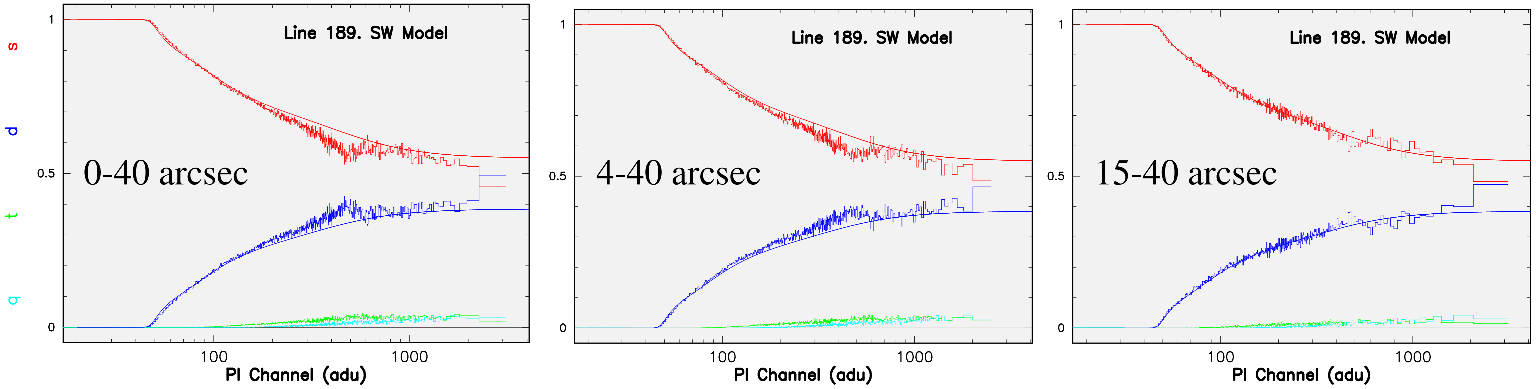
- see also Poster by F. Haberl et al. (WA2-14)

CAL STATUS/RESULTS: EVENT PATTERN STATISTIC – PILEUP

Shown on PKS2155



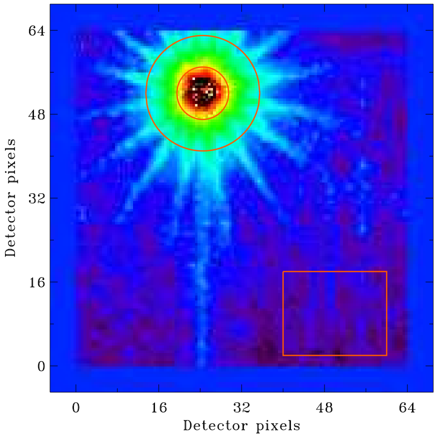
- separate spectra of singles/doubles/triplets/quadruplets
  note: effective thesholds are increasing
- in case of no pileup: s/d follow the solid line
- this SAS tool should be used to verify the size of the central part of the source which needs to be rejected for spectral fitting

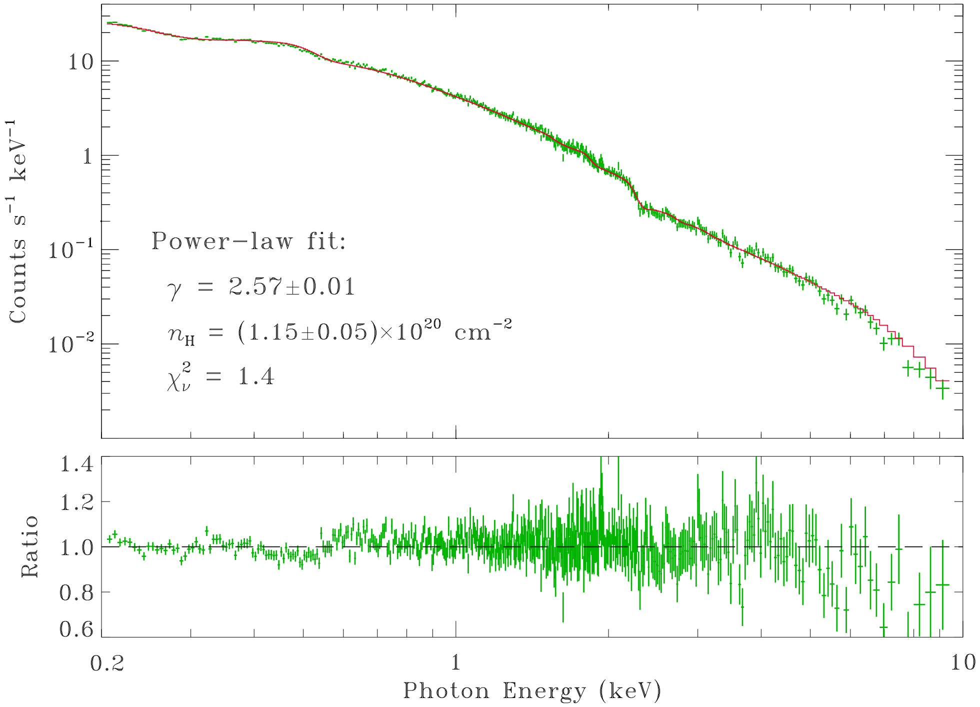


- see also Poster by F. Haberl et al. (WA2-14)

CAL STATUS/RESULTS: DETECTOR RESPONSE MATRIX

Spectral fit of a continuum source (shown on PKS2155)

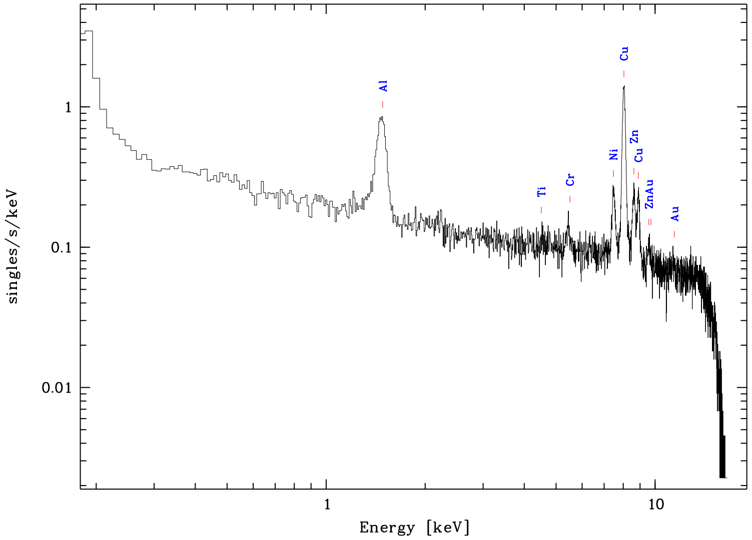




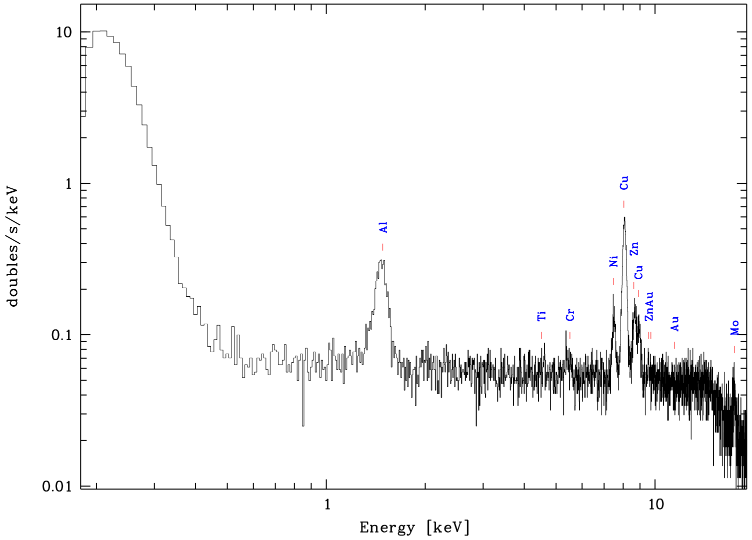
- red marked fields used for source and bkgd cts
- latest SW correction used
- residuals in the order of **5%**

CAL STATUS/RESULTS: INTERNAL PN BACKGROUND

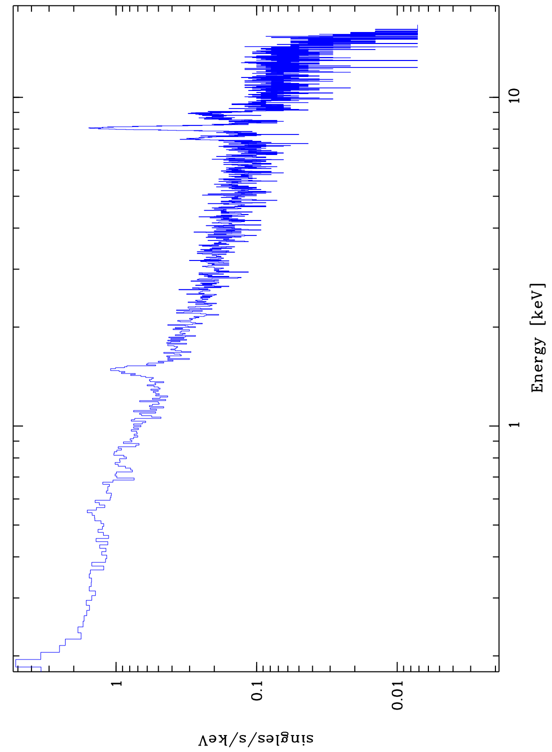
only singles



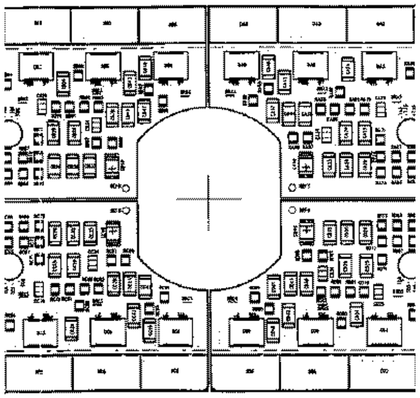
only doubles

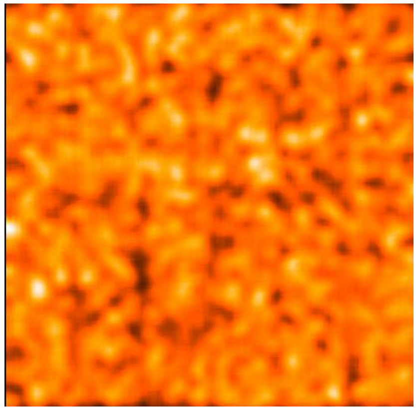


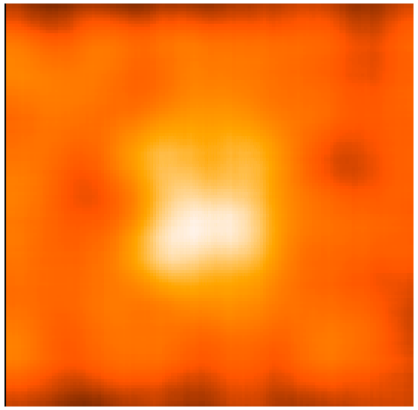
- background spectrum of entire sensitive detector area (∼32cm^2)
  filter wheel in closed position
- bkgd rate: $\sim 4.6 \times 10^{-3}$ cts/sec/arcmin^2/keV between 2 and 7 keV
    - see also Posters by M. Freyberg et al. (WA2-7/16)

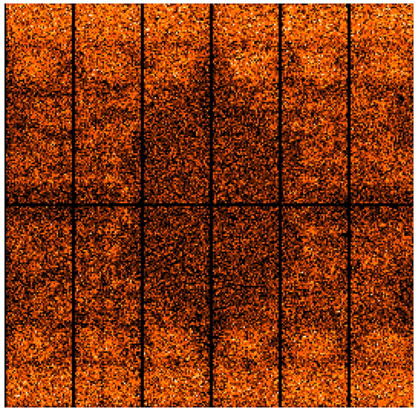

singles/s/keV
1
0.1
0.01
Energy [keV]
1
10

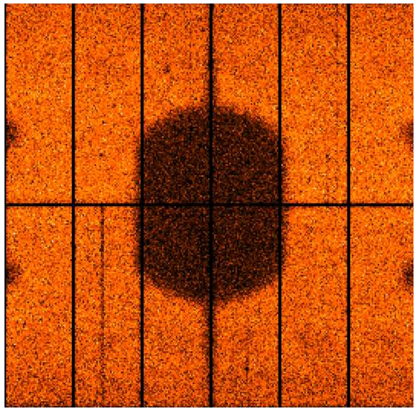
CAL STATUS/RESULTS: INTERNAL PN BACKGROUND

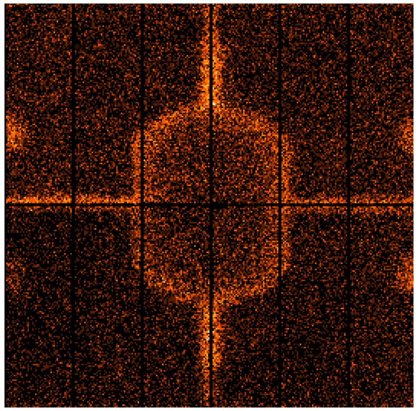

elctronic board


Al-K (1.44 – 1.64 keV)


Ti/V/Cr-K lines


Ni-K (7.3 – 7.6 keV)


Cu-K (7.8 – 8.2 keV)


Mo-K (17.1 – 17.7 keV)

- see also Posters by M. Freyberg et al. (WA2-7/16)

SUMMARY

- except for 4 weeks the pn-camera is operating very stable
- its calibration is monitored using internal cal source and cal targets
- the psf is estimated as expected from ground measurements
- the rel. and abs. astrometry is accurate to < 1 and < 5 arcsec respect.
- the effective area has been fine-tuned in orbit
- CTE is degrading as expected by approx. 2×10^{-5}/yr
- long term and temperature effects on CTE can be corrected
- cross-cal between different modes: X-ray line positions agree within 5 eV
- spectral fit to continuum source: residuals are in the order of 5%
- internal bkgd: detector intrinsic lines, variations across the FOV